AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. Contract ID Code Cost-Plus-Fixed-Fee	**Page** 1 **Of** 11		
2. Amendment/Modification No. P00007	**3. Effective Date** 2007APR05	**4. Requisition/Purchase Req No.** SEE SCHEDULE	**5. Project No. (If applicable)**

6. Issued By **Code** W56HZV

U.S. ARMY TACOM LCMC
AMSTA-AQ-ALEB
BARBARA PETERSON (586)574-7049
WARREN, MICHIGAN 48397-5000
HTTP://CONTRACTING.TACOM.ARMY.MIL
EMAIL: PETERSOB@TACOM.ARMY.MIL
WEAPON SYSTEM: WPN SYS: 00

7. Administered By (If other than Item 6) **Code** S3915A

DCMA PHILADELPHIA
700 ROBBINS AVENUE, BLDG 4-A
P.O. BOX 11427
PHILADELPHIA, PA 19111-0427

SCD C **PAS** NONE **ADP PT** HQ0337

8. Name And Address Of Contractor (No., Street, City, County, State and Zip Code)

K TECHNOLOGY CORP
2000 CABOT BOULEVARD WEST
150
LANGHORNE, PA 19047-2407

TYPE BUSINESS: Other Small Business Performing in U.S.

Code 09RK9 **Facility Code**

☐ **9A. Amendment Of Solicitation No.**

9B. Dated (See Item 11)

☒ **10A. Modification Of Contract/Order No.** W56HZV-04-C-0702

10B. Dated (See Item 13) 2004DEC15

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ **The above numbered solicitation is amended as set forth in item 14. The hour and date specified for receipt of Offers** ☐ **is extended,** ☐ **is not extended.**

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended by one of the following methods: (a) By completing items 8 and 15, and returning ____________ copies of the amendments: (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. Accounting And Appropriation Data (If required)
NO CHANGE TO OBLIGATION DATA

KIND MOD CODE: G

13. THIS ITEM ONLY APPLIES TO MODIFICATIONS OF CONTRACTS/ORDERS
It Modifies The Contract/Order No. As Described In Item 14.

☐ **A. This Change Order is Issued Pursuant To: The Changes Set Forth In Item 14 Are Made In The Contract/Order No. In Item 10A.**

☐ **B. The Above Numbered Contract/Order Is Modified To Reflect The Administrative Changes (such as changes in paying office, appropriation data, etc.) Set Forth In Item 14, Pursuant To The Authority of FAR 43.103(b).**

☒ **C. This Supplemental Agreement Is Entered Into Pursuant To Authority Of:** Mutual Agreement of both parties

☐ **D. Other (Specify type of modification and authority)**

E. IMPORTANT: Contractor ☐ **is not,** ☒ **is required to sign this document and return _______________ copies to the Issuing Office.**

14. Description Of Amendment/Modification (Organized by UCF section headings, including solicitation/contract subject matter where feasible.)

SEE SECOND PAGE FOR DESCRIPTION

Except as provided herein, all terms and conditions of the document referenced in item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. Name And Title Of Signer (Type or print)		**16A. Name And Title Of Contracting Officer (Type or print)** MICHAEL L. CIONI CIONIM@TACOM.ARMY.MIL (586)574-7070	
15B. Contractor/Offeror ______________ (Signature of person authorized to sign)	**15C. Date Signed**	**16B. United States Of America** By /SIGNED/ (Signature of Contracting Officer)	**16C. Date Signed** 2007APR05

Name of Offeror or Contractor: K TECHNOLOGY CORP

SECTION A - SUPPLEMENTAL INFORMATION

PROGRAM: SBIR Phase II and III with K TECHNOLOGY CORPORATION

PURPOSE OF THE MODIFICATION: Extension of the performance completion date on both the Phase II and III portions of the contract.

1. This is a bi-lateral modification.

2. The purpose of this modification is to extend the period of performance of the Phase II contract from April 30, 2007 to October 31, 2007, at no additional cost to the Government.

3. The period of performance for the Phase III contract is extended from March 10, 2007 to October 31, 2007 at no additional cost to the Government.

4. The Contract is modified as follows:

Section C Revisions are also identified as follows:

a. A modification to the inverter stand that will provide the capability to test the inverters while the motor is operating in regenerative braking mode. Section C.17.8 is revised to accommodate this change.

b. Section C.17.7.1 is also revised to accommodate changes in testing requirements.

c. Section C.18.2 Hardware deliverables is also revised.

Section F is revised to reflect the extended period of performance for the Phase II and III efforts as set forth in F.2 and F.2.1

5. As a result of this action the total amount of the contract is neither increased or decreased.

6. All other terms and conditions of the contract remain unchanged and in full force and effect.

*** END OF NARRATIVE A 0006 ***

SECTION C - DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

SECTION C: STATEMENT OF WORK (SOW)

C.1. Background Information

The Contractor shall develop the material technologies and the design configurations of an Integrated Thermal Module (ITM) capable of cooling high power silicon and silicon-carbide (SiC) based power converters. Contractor shall integrate, package, and demonstrate the ITM in power modules (PM) and high voltage motor drive converters. Contractor shall obtain input from potential power module users to insure that the resulting ITM will have potential applications in high-power emerging SiC and other power switching products.

C.2. Design Targets and Specifications

Contractor shall develop the design specifications, evaluation procedures and certification procedures for the integrated thermal module (ITM). Packaging details of the components including all thermal interfaces, will be considered. This task shall define the ITM performance goals, design parameter targets, and integration/interface requirements.

C.2.1 Develop ITM Design specifications
Contractor shall consider the design requirements of the ITM. The power module interface requirements shall address the coefficient of thermal expansion (CTE) match between the mounted power semiconductor devices/substrate and the ITM, and desired electrical characteristics. Design specifications will consider options to integrate the ITM into the substrate of the power module.
The structural requirements of thee designs shall come from the operation loads and maximum allowable deflections the assembly will experience in use. The thermal requirements shall come from the maximum allowable component temperatures and maximum allowable temperature gradient. Out-gassing, compatibility with solvents, and long-term reliability issues shall be addressed.

C.2.2 ITM Preliminary Design
Based upon specifications, requirements and geometry constraints developed in C.2.1, Contractor shall establish a preliminary layout design of the ITM assembly. From this layout, through analysis, Contractor shall size all the components. The baseline layout shall be used to select the materials and composite architectures presented in the following sections.

C.2.3. Impact of ITM Components on Emerging Designs
The Contractor shall obtain input from the COR concerning thermal management approaches under consideration in other Army programs. On the basis of this information, the Contractor shall estimate the thermal benefits of the ITM and/or its components on Army applications.

C.3. ITM Encapsulant Materials and Low-Cost Manufacturing

. Aluminum encapsulation shall provide the baseline performance to compare other encapsulants with. Thermal expansion, manufacturing costs, and electrical characteristics are important, and determine the effectiveness of the ITM in the Power Module (PM).

C.3.1 Evaluation of Thermal Expansion Coefficient of ITM Encapsulation Materials
Phase I contract DAAE07-03-C-L069 demonstrated the feasibility of using aluminum-silicon (Al-Si), a novel high performance low-CTE encapsulant in the ITM. A matched coefficient of thermal expansion (CTE) between PM components and the ITM allows use of joining techniques with lower thermal resistance. The encapsulant material determines the CTE. The encapsulant material type has a strong effect on the thermal properties, and determines the mechanical properties of the ITM interface to the power module.

Contractor shall study encapsulants materials and identify candidate encapsulants materials based on their capability to achieve a CTE match with ITM and PM components. At a minimum, two general classes of material will be studied, metallic encapsulants, and ceramic encapsulants.. The ceramic encapsulants, AlSi, and the metallic encapsulants, Kovar, shall be studied and compared with the baseline metallic encapsulants, aluminum.. Al-Si metal matrix composites (MMC) posses a uniform microstructure of fine silicon particles in an aluminum matrix. Al-Si has similar thermal and mechanical properties to the AlSiC MMC.

C.3.2 Low Cost Manufacturing Techniques
The Contractor shall investigate near net shape forming techniques including semi solid processing, and PPM (pressed powder metallurgy).

C.3.2.1 Semi Solid Processing (SSP)
SSP is a low-cost high production volume process for manufacturing precision metal and metal matrix composite parts, similar to die casting or plastic injection molding. Contractor shall perform an industry survey of vendors who have the capability to perform semi-solid processing (SSP). Contractor shallassess and make recommendations to the COR whether the SSP process can be used for the encapsulants considered. The Contractor shall investigate SSP (also called thixotropic processing) to form the encapsulated APG heat spreader blanks to near net shape. Contractor shall subsequently machine the encapsulated APG blanks to the exact final form. Contractor shall produce material samples of pre-machined encapsulated Anealled Pyrolytic Graphite (APG) blanks. Contractor shall refine and repeat the process to determine if it will meet the heat spreader design specifications defined in C.2. Contractor shall perform as many process trials as necessary in order to produce a minimum of 5 heat spreaders. Contractor shall document the

established process.

C.3.3.2 Pressed Powder Metallurgy (PPM) and Sintering Process
The contractor shall investigate the use of PPM to fabricate ITM.

C.4. Material Property verification tests

The contractor shall design and fabricate test coupons using the encapsulants materials, formulations, and low-cost fabrication processes identified in Tasks C.3.1 and C.3.2. Contractor shall measure the perform of the encapsulated APG material properties with kTC Process Specification (PS031) for material evaluation. These tests may identify manufacturing or design problems associated with the material formulations. If such problems are identified, Contractor shall implement improvements in the component designs in order to mitigate or eliminate any identified manufacturing or design problem.

C.5. Thermal Via Development

In Phase I, thermal vias were found to improve heat spreader performance. The vias must be properly designed. The proper via geometry, position and number must be determined.

C.5.1 Metal-Graphite Via Material Development
The objective of this task is to develop a via material with higher thermal conductivity, lower CTE, and lower density (for lighter weight), than copper. In this task, the Contractor shall develop a metal matrix composite (MMC). The contractor shall develop the material and produce at least two batches with different volume fractions. The contractor shall perform hot isostatic pressing to produce billets of two different materials. The contractor shall prepare evaluation coupons from the billets. Contractor shall determine the CTE of the coupons and compare the results with expected values. The contractor shall prepare additional coupon samples and perform the seven evaluation tests indicated in C.4. The contractor shall perform sectioning and visual inspection of a number of additional coupon samples. The contractor shall perform micrographs, and shall assess the distribution of the reinforcement and the integrity of the microstructure.

C.5.2. Sensitivity Analysis of Via Properties
A number of via parameters may affect the thermal performance of the heat spreader. These include thermal conductivity, geometry, placement relative to heat generating semiconductor chips, and interface issues. Contractor shall assess the sensitivity of heat spreader thermal performance to these different design parameters by using finite element method (FEM) analysis. Practical limits on these parameters will be determined. FEM simulations will be performed varying these parameters within these practical limits.. If a parameter shows a significant impact on heat spreader thermal performance, optimization will be performed to determine the best via design.

C.5.3. Via Optimization
The contractor shall use a FEM analysis to optimize the thermal conductance of the ITM. The analysis shall determine via geometry and size design parameters to achieve minimum temperature gradient.

C.6. Heat Exchanger Design

The heat exchanger shall be designed to cool silicon carbide (SiC) semiconductor components using high temperature fluid cooling up to 100 degrees Celsisus.

C.6.1 Heat Exchanger Design Concepts
Contractor shall identify advanced heat exchanger design concepts to minimize the thermal resistance of the ITM, and maximize the heat transfer to the cooling fluid. Porous foams shall be considered as a heat exchanger element. Limited use of nano-particles may be considered to improve heat exchanger fluid coupling.

C.6.2. Heat Exchanger Design
Heat exchanger concepts shall be assessed and evaluated in the context of its use with other ITM components, including encapsulation materials, thermal vias, and heat spreader design. Contractor shall develop a detailed heat exchanger design.

C.7. Integrated Thermal Module (ITM) Design

The ITM is composed of k-Core encapsulated APG heat spreader and heat exchanger. Contractor shall perform a preliminary design which will subsequently be subjected to a design review by semiconductor power module manufacturer and application developer. Contractor shall subsequently assess their suggestions and upon concurrence with the COR, incorporate changes, perform a detailed analysis, and perform a final detailed design.

C.7.1 ITM Preliminary Design/Analysis

Contractor shall establish a baseline ITM design using standard engineering practices. Design shall include known material performance criteria and design requirements. Packaging design requirements will be used to establish the sizing and placement of the APG within the encapsulated APG heat spreader. Standard engineering design rules and calculations will be used to determine sections thickness and component sizing. Contractor shall use computer aided design (CAD) software to create a model of the layout. A preliminary design review shall be held with Contractor, a power module manufacturer, and an applications representative. Upon concurrrence with the COR, the recommended improvements and changes shall be incorporated and the CAD model shall be updated.

C.7.2 Detailed Design of ITM

The preliminary design will be analyzed in detail, to assess its performance for use in host application power modules. Baseline geometry will be finalized following system optimization. The contractor shall utilize the via optimization procedure developed in C.5.3 to maximize the thermal conductance of the system. The resulting design will be reviewed and modification will be made to address manufacturability and cost avoidance issues.

C.7.3. Final Design and Documentation

Contractor shall finalize the design and engineering of the ITM. A complete set of engineering drawings will be created. The set of drawings will include, 1) inspection drawings, 2) fabrication drawings showing the assembly and machining details, 3) center frame drawings showing the internal details of the design, and 4) APG machining drawings.

C.8. Power Module and Converter Design

The power module shall be designed to operate with high coolant temperatures up to 100 degrees C. High-power power modules will be designed to operate in the 50kW to 500kW range. Power modules will be designed for improved reliability and life to accommodate frequent bursts of high power. The converter shall use a standard six-switch, hard -switched topology.. The contractor shall develop an ITM which can be used with SiC devices. If suitable SiC main power switched are not available commercially over the course of this contract, the contractor shall design a PM which uses anti-parallel SiC Schottky rectifiers and silicon IGBTs (insulated gate bipolar transistors).

C.9. Power Module Design

C.9.1 Alternative Power Module Designs

The Contractor shall develop, for purposes of analysis and quantitative comparison, designs for a set of alternative constructions of the power switch module using the ITM. At a minimum, two designs for alternative constructions of the power switch module will be produced, based on the different encapsulants materials tested in Section C.3. These alternative constructions may use the encapsulant materials specified, Kovar and Al-Si, or may use alternative materials if the provide superior performance.

The alternative designs will be analyzed to assess the relative performance in converters for heavy traction applications. Trade off studies will investigate and rank the performance of the various material and process combinations. Consideration will be given to issues such as: device temperature, system power density, thermal expansion stresses, efficiency, and economic viability. In addition to steady state operation, the contractor shall consider the transient burst power which is characteristic of heavy vehicle propulsion. The best design shall be recommended to the COR and with COR approval, detailed design shall be completed for appropriate modifications to the power modules.

The Contractor shall develop an alternative design consisting of an all-silicon carbide rectifier power module with the capability of operating at higher coolant temperature. The target coolant temperature is 120 degrees C. The Contractor shall fabricate at least one high-temperature silicon carbide diode power module using commercially available silicon carbide rectifier die. Silicon carbide rectifier voltage and current ratings shall be similar to that of the siliconcarbide rectifiers used in the Power Module designed for operation using 100 degree C cooolant. The Contractor shall perform performance at coolant temperatures up to the target 120 degrees C.

C.9.2 Converter Design Prototype Evaluation/Validation

Using the power module design, alternatives for the Converter Package design will be developed. A preferred alternative shall be selected and upon concurrence of the COR the detailed design shall be performed that includes the power module, ITM, cooling system, capacitor bus, housing, and gate drive. The current sensors and controls required for a complete motor drive shall be attached externally.

C.10. Fabrication

C.10.1 Integrated Thermal Modules

Contractor shall fabricate at least six ITMs to the detailed design drawings. A minimum of two of these modules will be used for contractor testing. A minimum of two will be used to mate with power module from semiconductor manufacturer.s. A minimum of two will be used for integration into the demonstrator power converter.

C.10.2 Power Module Modifications

Consistent with the detailed design in C.9.1, Contractor shall produce at least two power modules compatible with ITMs fabricated in C.10.1.

C.10.3 Converter Fabrication and Assembly
Consistent with the detailed design in C.9.2, Contractor shall fabricate a power converter that integrates the a power module that incorporates the ITM along with standard converter elements.

C.11. Evaluation and Qualification

C.11.1. Evaluation
Contractor shall evaluate the ITM, consisting of an integrated heat spreader and heat exchanger, integrated into a PM and operating under simulated load in a traction motor converter. Contractor shall determine the critical performance characteristics of the design and materials through testing.

Contractor shall establish an evaluation procedure and have this procedure reviewed by the COR. The procedure will define the type, number and configuration of all the evaluation tasks. The procedure will simulate the workload and conditions, the ITM would experience in a fielded system. Comments back from the COR shall be reviewed and if appropriate included in the document. This evaluation procedure shall then be used in the characterization of the heat exchangers.

The Contractor shall evaluate the thermal performance of the ITM per the process defined in the evaluation procedure. This data will be used to verify the performance improvements of the encapsulated APG design. The evaluations will involve a thermal simulation that will mimic the thermal loading of the heat spreader. The heat spreaders will be instrumented and steady state temperatures will be recorded.

C.11.2 Data Correlation and Design Refinement
The Contractor shall review the collected data and correlate it to the predictions. Areas of compliance and non-compliance will be identified. Contractor shall determine, if the non-compliance features are due to poor design or manufacturing flaws, and then take corrective action. The result of this effort will be either a refined design or a validation of the produced items.

Contractor shall develop, test and evaluate the prototype modules to validate their thermal and electrical performance. Basic functional tests shall be performed with a permanent magnet motor. Power characterization tests shall be performed using passive inductive loads. The thermal and electrical measurements shall be correlated with the analysis, accounting for the test load conditions.

C.11.3. Qualification Specification
Contractor shall develop a qualification specification for the ITM, and shall provide it to the COR for review. COR shall review and provide recommendations to the Contractor, as needed.

C.11.4. Qualification Procedure
Contractor shall implement the qualification procedure as defined in C.11.3. Qualification Specification.
Contractor shall obtain power module manufacturer and potential user(s) recommendations.
The qualification procedure will be applied to the assembly using actual power modules that incorporate the ITM.

Contractor shall review the qualification results, and identify any failures or deficiencies in power module performance. Contractor shall identify the cause of any failures or deficiencies, and determine if they are related to an inadequate design or to a material deficiency. Contractor shall revise ITM and PM design, as appropriate. Contractor shall document all changes. Contractor shall re-test the PM, if required.

C.12. Production Design

C.12.1 Process Development
The production design task is to review all of the demonstrated encapsulated APG designs and processes and incorporate any design and process improvements that will either lower production costs or improve performance. Upon concurrence of the COR the contractor shall incorporate all of the design and process improvements identified into the component drawings.

In addition to incorporating the design and process improvements into the encapsulated APG designs, the Contractor shall develop production-tooling designs that will support higher volume batch processes. The objective is to lower costs through higher volume production. This will require additional tooling, which will be identified in this task.

C.12.2 Design Parameter Impact on Process
In addition to the process parameters, the Contractor shall seek broader user input. The Contractor shall seek user input for evaluation and determination of the key production needs driven by am integrated thermal module for a broader range of applications including fuel cell systems, and industrial high power motors. The Contractor shall employ a House of Quality method for this product development effort.

C.13. Deliverables

C.13.1 Status/Management Reports

The contractor shall prepare quarterly status reports in accordance with CDRL item A001. The status reports shall summarize the work completed; the contract tasks not completed and significant accomplishments, problems or delays. The reports shall include the status of on-going studies and studies completed during the reporting time period, as well as test results and their interpretation. The status reports shall also report all total costs incurred to date, with specific reference to the cost incurred since the last status report.

C.13.2. Final Technical Report

The contractor shall prepare a draft final report in accordance with CDRL data item A002 and deliver to the COR in 22 months after the contract award. The COR shall review the draft final report and return it to the contractor within 30 days of receipt of draft with comments. The contractor shall submit one (1) final Scientific and Technical Report within 30 days after the receipt of the draft comments and shall incorporate the CORs comments in the final report.

C.14. Hardware:

C.14.1. At the final review, the contractor shall deliver two (2) power modules incorporating the advanced heat spreader fabricated in C.10.2. Also at the final review the Contractor shall deliver one high temperature silicon carbide power module capable of using 120 degree C coolant temperature, developed in Section C.9.1.

C.1.4..2 The contractor shall deliver the inverter fabricated in C.10.3 to the COR at TACOM within 24 months after contract award. Inverter shall be packaged in a manner to insure that no components are damaged due to shock, vibration, or impact during transit.

C.15. Meetings

C.15.1 Start of Work Meeting:

Start of Work meeting shall be held at TACOM or by telecon no later than (NLT) 30 days after contract award or as mutually agreeable with the Contracting Officers Representative (COR). At this meeting, the contractor shall present their planned approach to complete the contract effort. The contractor shall coordinate with the Contracting Officers Representative (COR) to schedule a specific date and time.

C.15.2 Annual Review:

The annual review meeting shall be held at either TACOM or the contractor's facility no later than 12 months after the award of the contract. For the annual review, the contractor shall provide a comprehensive presentation including a discussion of activities performed, tasks completed, measured performance.

C.15.3 Final Review:

The final review meeting shall be held at either TACOM or the contractor's facility no later than 23 months after the award of the contract. For the final review, the contractor shall provide a comprehensive presentation including a discussion of the following:

1) Design and Analysis of Advanced Heat Spreader,
2) Power Module Design and Fabrication,
3) Heat Spreader and Power Module Evaluation,
4) Inverter Testing and Documentation,
5) Commercialization Planning.

C.16 Phase III Objectives

The contractor shall develop an advanced heat spreader capable of reducing temperature rise in high power silicon-based power converters. Contractor shall produce working beta heat spreaders that will be evaluated by insertion and testing in commercially available semiconductor power modules, and qualified in an high-voltage electric motor drive inverter.

C.17 Tasks

In order to accomplish the objectives of this program, the contractor shall conduct the following key and complementary tasks:

C.17.1 Task A. Target Power Module Selection and Advanced Heat Spreader Specification

C.17.1.1 Target Power Module Selection

Contractor shall identify silicon-based power modules for APG (annealed pyrolytic graphite) advanced heat spreader technology insertion. Consideration will include selection from existing Semikron power modules that have both widespread applications and the capability to be used as building blocks for a traction motor drive inverter and other electric vehicle applications. The effort will set performance goals and design parameter targets. Contractor shall select target power module device type, number of devices per package, device interconnection, heat exchanger type, and power level. Target modules will consider both air-cooled and fluid cooled power modules. One of the options for consideration will be the Automotive Integrated Power Module (AIPM) that Semikron is currently developing.

C.17.1.2 Design Specifications

Contractor shall establish the thermal and structural design requirements of the advanced heat spreader, and power module interface requirements. The structural requirements of these designs will come from the operation loads and maximum allowable deflections the assembly will experience in use. The thermal requirements will come from the maximum allowable component temperatures and maximum allowable temperature gradient. Other issues such as, out-gassing, compatibility with solvents, and long-term reliability will all be included. Contractor shall establish the design specifications.

C.17.2 Task B. Advanced Heat Spreader Design Concepts

Based upon the specifications developed in Task 1, requirements and geometry constraints, contractor shall establish a set of heat spreader design constraints that will include interface requirements with semiconductor chip substrates, interface requirements with the heat exchanger, and heat transfer requirements. Within these constraints, contractor shall investigate several design options for the AHS (Advanced Heat Spreader) component. These options will include choice of CTE-matched encapsulants, thickness of APG, and thermal via design and placement.

C.17.2.1 Documentation and CAD Models

Contractor shall document advanced heat spreader design options and develop CAD models of each. Contractor shall conduct preliminary thermal analyses on each of the design options. Power Module compatibility with electric motor drive inverter applications will be reviewed and documented.

C.17.2.2 Team Review and AHS Design Selection

A meeting will be held at TACOM to review the design approaches for the advanced heat spreader. Personnel from TARDEC, and the contractors team, will attend. Based on the review, contractor shall select the best design approach for near term technology insertion of the AHS in the target power module (selected in Task A, Section C.17.1.1)

C.17.3 Task C. Detailed Design and Analysis of Advanced Heat Spreader

Contractor shall perform a detailed analysis of the selected AHS design. The analysis will include thermal performance, dynamic mechanical performance (shock and vibration), structural, and compatibility requirements.

C.17.3.1 Finite Element Methods (FEM) and Analysis

Contractor shall develop 3-dimensional FEM models for analysis of chosen advanced heat spreader configuration. The FEM will include detail so that through-the-thickness vias can be represented, and to model heat transfer from the non-uniform semiconductor chip heat sources to the heat exchanger and coolant on the underside of the heat spreader. Contractor shall employ FEM model optimization routines to determine the most effective via placement and shape. The heat spreader design will be tailored to the chosen type of heat exchanger whether it be air or water cooled.

C.17.3.2 Drawings and Design Reviews

Once the heat spreader is fully analyzed, contractor shall develop complete drawings so that the heat spreader is form fit to an existing power module. Drawings will include installation drawings into the selected power module. Once the drawings are completed, the module design will be reviewed by the Contractors team, and the drawings released for manufacture.

C.17.4 Task D. Advanced Heat Spreader Prototype Fabrication

Contractor shall fabricate a minimum of six advanced heat spreader prototypes using lowest cost processes currently available from k-Technologys latest proven low-cost manufacturing methods for both encapsulants and APG. Each of the heat spreaders will under go quality reviews according to k-Technology ISO9001 quality procedures. A minimum of two of these heat spreaders will be used for testing. A minimum of two of the heat spreaders will be used for insertion and testing in Semikron Power modules. A minimum of two will be used for specialized testing in preparations for insertion of the power modules into Comprehensive Powers power converter the test inverter to be fabricated in Task G
(Section C.17.7).

C.17.5 Task E. Power Module Assembly

C.17.5.1 Method of Substrate Attachment

As part of the assembly process, contractor shall investigate methods to attach the chip substrate to the advanced heat spreader. Contractor shall consider both the thermal paste method currently employed by Semikron, and brazing or soldering for module assembly. The selection will be determined by the trade off between rapid market insertion versus enhanced thermal performance.

C.17.5.2 Power module assembly

Contractor shall install advanced heat spreader prototypes fabricated in task D, Section C.17.4, into standard Semikron power modules. Power modules shall be fit and form compatible with existing power converter systems.

C.17.6 Task F. Heat Spreader and Power Module Evaluation

Contractor shall test the prototype advanced heat spreaders fabricated in Task 4 as stand alone components. Contractor shall test and evaluate the power modules assembled in Task E (Section 17.5.2) using the prototype advanced heat spreaders.

C.17.6.1 Advanced Heat Spreader Evaluation
Contractor shall perform thermal and mechanical testing of the prototype advanced heat spreaders. Thermal testing will be performed before subjecting to mechanical loads, corresponding to beginning of life (BOL). Contractor shall subject heat spreaders to dynamic mechanical loads. Thermal testing will again be performed after subjecting to mechanical loads, corresponding to end of life (EOL). Contractor shall compared results of thermal testing with FEM predictions made in Task C (Section C.17.3.1).

C.17.6.2 Power Module Evaluation
Contractor shall test power modules containing advanced heat spreaders under realistic electric loads and responses typically used in qualification of their power modules. As is standard with power module product qualification, contractor shall use a voltage drop test to evaluate the heat transfer path from chip to the heat exchanger. Contractor shall subject the power module to routine power module qualification tests.

C.17.7 Task G. Inverter Fabrication

Contractor shall assemble an electric motor-drive inverters for evaluation and comparison of advanced cooling technologies. These inverters shall be nominally rated at 100kW and designed to run a permanent magnet motor of 100kW continuous power or greater.

C.17.7.1 Contractor shall assemble 2 inverters and 2 inverter cold-plate cooling modules:

*

One using advanced heat spreader modules and silicon carbide rectifiers,

*

One using advanced heat spreader modules and silicon rectifiers,

*

One inverter cold-plate cooling module suitable for oil cooling

*

One inverter cold-plate cooling module suitable for water cooling .

*

C.17.7.2 The contractor shall design and fabricate four inverter control modules including hardware and wmbedded software. One of these modules will be configured for use controlling the inverter using silicon carbide rectifiers.

C.17.7.3 The contractor shall assemble one inverter module incorporating the integrated thermal module (ITM) for bench diagnostic testing.

C.17.8 Task H. Inverter Thermal Management Test Stand

The contractor shall design, fabricate and test a thermal management test stand according to the following requirements:
The test stand will include provisions for inverter power, control, cooling, and the appropriate electrical and thermal sensor needed to measure inverter electrical and thermal performance while driving the test stand high power permanent magnet motor.
The test stand shall have the capability to switch-out inverter and inverter control packages to allow comparison between inverter cooling technologies.
The test stand shall include two permanent magnet motors capable of operating at 100kW power or greater, for a period of 10 minutes or longer. *
The test stand shall include cooling loop capability for both oil and propylene-glycol coolants, as well as needed radiators, pumps, fans, and cooling sensors for temperature, pressure, and flow rate.
The test stand shall be designed to operate from an externally supplied 600V power supply.

C.17.9 Task I. Inverter Testing

The contractor shall subject the motor drive inverters using advanced heat spreaders, fabricated according to C.17.7.1, to demanding electrical and thermal operation designed to determine the full thermal capability of the power modules fabricated with advanced heat spreaders. The contractor shall subject the motor drive inverters using other cold plate cooling technologies along with silicon rectifiers, fabricated according to C.17.7.1, to similar demanding electrical and thermal operation designed to determine the full thermal capability of these power modules and cooling technologies.

C.17.10 Task J. Commercialization Planning

Contractor shall develop a plan to insert the advanced heat spreader technology into a power module production line.

C.18. Hardware:

C.18.1. At the final review, the contractor shall deliver two (2) power modules, incorporating the advanced heat spreader, fabricated in TASK E (Section C.17.5).

C.18.2. The contractor shall deliver the inverters and inverter cold-plate cooling modules specified in TASK G (Section C.17.7) and the inverter control modules as specified in section * C.17.7.2, to the COR at TACOM within 28 months after contract award. Inverter and inverter control modules shall be packaged in a manner to insure that no components are damaged * due to shock, vibration, or impact during transit.

C.18.3 The contractor shall deliver one inverter module incorporating the integrated thermal module (ITM) as specified in section C.17.7.3 to the COR at TACOM within 28 months after contract award. Inverter module shall be packaged in a manner to insure that no damaged due to shock, vibration, or impact will occur during transit.

C.18.4 The contractor shall deliver one inverter test stand as specified in section C.17.8 Task H, to the COR at TACOM within 28 months after contract award. Inverter test stand shall be packaged in a manner to insure that no components are damaged due to shock, vibration, or impact during transit.

C.19. Meetings Phase III

C.19.1 Start of Work Meeting:
Start of Work meeting shall be held at TACOM no later than (NLT) 30 days after award of Contract modification P00001 or as mutually agreeable with the Contracting Officers Representative (COR). At this meeting, the contractor shall present their planned approach to complete the contract effort. The contractor shall coordinate with the Contracting Officers Representative (COR) to schedule a specific date and time.

C.19.2 Advanced Heat Spreader (AHS) Design Selection Review:
An AHS Design Selection Review meeting will be held at TACOM to review the design approaches for the advanced heat spreader, as described in Section C.3.2.2. The COR and personnel from K-Technology, Semikron, and Comprehensive Power will attend. Based on the review, contractor shall select the best design approach for near term technology insertion of the AHS in the target power module selected in Task A (Section C.17.1.1) The contractor shall coordinate with the Contracting Officers Representative (COR) to schedule a specific date and time.

*** END OF NARRATIVE C 0001 ***

SECTION F - DELIVERIES OR PERFORMANCE

F.1.1 Data

F.1.2 The delivery schedule for the data items is found on Exhibit A, The Contract Data Requirements List (DD Form 1223).

F.1.3. All data deliverables under this contract shall be delivered electronically to the email addresses specified in the Contract Data Requirements List (CDRL) DD Form 1423.

F.2 Period of Performance

The period of performance of the base Phase II effort (CLIN 0001) shall be through October 31, 2007. *

F.2.1 The period of performance for the Phase III portion of this contract (CLIN 0003) shall be through October 31, 2007. *

F.3 hardcopy documents, if required to be delivered under the terms of this contract, shall be shipped FOB Destination to the following address:

U.S.Army TACOM
Attn: AMSTA-TR-N (Terence Burke) Mailstop 121

6501 E. 11 Mile Road
Warren, MI 48397-5000

All other deliverables must be sent by e-mail to the following addresses unless alternative arrangements are made with the Contracting Officer's Representative:

burket@tacom.army.mil, and lawrencp@tacom.army.mil.

* revised by Modification P00007

*** END OF NARRATIVE F 0001 ***